

### Sensitivity of Waste Management Results to Separations and Recovery Efficiency Assumptions

In the analyses presented, the assumption has been made that for cases where spent fuel is processed, the loss of desired materials into the waste streams is 0.1%. The losses can occur in the separations plant prior to obtaining the desired products or during fuel fabrication as the products are used. The origin of the goal of 0.1% loss is from earlier estimates generated in the AFCI program for peak dose rate associated with releases from a geologic repository and from estimates of the impact of decay heat on the utilization of space in a geologic repository like Yucca Mountain. At that time, using the modeling that had been developed for analyzing the Yucca Mountain repository, it was shown that when processing spent PWR fuel, if the TRU loss to the waste stream was 1.0%, the TRU in the wastes still determined the estimated peak dose rate. However, when the TRU loss to the waste stream was 0.1%, the estimated peak dose rate was determined by other isotopes in the wastes such as Tc-99 and I-129. As a result, a value of 0.1% was selected as a goal for TRU losses to the waste streams. This goal was not modified for the processing of spent fast reactor fuel, although even at 0.1% TRU loss to the waste stream, the actinides still dominated the estimated peak dose rate and the thermal load in the repository.

A similar situation was observed for the removal of cesium and strontium from the waste stream with regards to decay heat and the impact on loading of a repository like Yucca Mountain. With such high recovery of the TRU, there were significant gains in loading as losses of cesium and strontium were reduced down to 1.0%. Further reduction in the loss of cesium and strontium to 0.1% to the waste stream showed that the rate of improvement in the loading of the repository decreased significantly, indicating that the optimum recovery goal for cesium and strontium would be somewhere between 0.1% and 1.0% when TRU losses were also set at 0.1%. As a result, the goal for all separations and process losses for both TRU and Cs/Sr was set at 0.1%, realizing that such a low loss for all operations would be considered an aggressive target to meet, not necessarily for technical reasons but more for economic ones.

The sensitivity of the waste management metrics to a higher loss rate must be evaluated by consideration of each of the alternatives where separations and fuel fabrication with recovered materials is required, since not all cases involve recovery of TRU and Cs/Sr. The waste management metrics are volume of SNF disposed in the repository, volume of HLW, GTCC, and LLW wastes, the reduction in thermal load on the repository, and the reduction in radiotoxicity of the waste (changed from evaluating estimated peak dose rate as a result of more recent modeling and analysis results proposed for the Yucca Mountain repository by DOE-OCRWM).

1. LWR/LWR (MOX-U-Pu) alternative - Only plutonium and Cs/Sr is separated and recovered. In this case, only plutonium is being recovered. If the losses of plutonium to the waste streams were higher than 0.1%, the impact on the waste management metrics would be as follows:
  - a. Since there is no disposal of SNF for this alternative, a higher loss rate would have no impact.

- b. The volume of HLW is dominated by the fission products. In this case, the minor actinides are also in the HLW. The addition of a small amount of plutonium, such as would occur if the loss rate were 1% instead of 0.1%, would make little difference. Similarly with the GTCC, as this is dominated by the cladding and assembly hardware from the spent fuel, along with other wastes from processing and operations. If the loss of plutonium is to waste streams that would be designated LLW, such loss would increase the volume of LLW, since in order for wastes to be LLW, they must have very low concentrations of plutonium, along with curium and other actinide alpha emitters (10CFR61.55), or the loss would result in the waste being reclassified as GTCC.
  - c. The thermal load reduction factor for this case is estimated at a factor of 1.8 due to the presence of the minor actinides in the HLW. Since all of the americium and curium are already in the HLW, an increase in plutonium loss from 0.1% to 1.0% would have essentially no impact on this factor.
  - d. The reduction in radiotoxicity of the HLW for this case is modest, a factor of about 4 at the time the radiotoxicity has been reduced to that of the natural uranium ore from which the fuel originated (55,000 years as compared to 240,000 years). An increase in loss of plutonium to the HLW from 0.1% to 1.0% would have little effect in increasing the radiotoxicity, since the radiotoxicity is dominated by isotopes of other chemical elements.
2. LWR/HWR (DUPIC) alternative – There is no chemical separation or recovery of any of the chemical elements in this case. Volatile fission products are captured and disposed as HLW. At the end of the DUPIC approach, the spent HWR fuel is directly disposed in the repository. There is an implied assumption about the loss of spent LWR fuel in the OREOX process, but since the residuals of this process go to either HLW or possibly GTCC that would require geologic disposal, if the loss is higher at this stage, then there is less HWR spent fuel that also goes to the repository. Overall, there should be little effect on disposal requirements.
3. Fast reactor recycle alternative – All spent LWR fuel and spent fast reactor fuel are processed, and the TRU and the Cs/Sr are separated and recovered. In this case, there is a larger impact with a higher loss to the waste streams.
- a. Since there is no disposal of SNF for this alternative, a higher loss rate would have no impact.
  - b. The volume of HLW is dominated by the fission products. The addition of a small amount of TRU, such as would occur if the loss rate were 1% instead of 0.1%, would make little difference. Similarly with the GTCC, as this is dominated by the cladding and assembly hardware from the spent fuel, along with other wastes from processing and operations. If the loss of TRU is to waste streams that would be designated LLW, such loss would increase the volume of LLW, since in order for wastes to be LLW, they must have very low concentrations of plutonium, along with curium and other actinide alpha emitters (10CFR61.55), or the loss would result in the waste being reclassified as GTCC.
  - c. The thermal load reduction factor for this case is estimated at a factor of 235 due to the very low level of TRU in the HLW. Analyses have not been

performed at higher loss fractions for the combination of fast and thermal reactors, but based on the analyses for these two reactor types individually, it can be estimated that an increase in TRU loss from 0.1% to 1.0% would decrease this factor to the range of about 15-90, with losses from processing the fast spent reactor fuel being much more important in affecting the thermal load from the waste. Higher TRU losses would reduce the factor even further, so that with 10% loss to the HLW, it is the thermal load reduction factor would still be in the vicinity of 1.5-60, again with losses from processing fast reactor fuel being much more important. Higher losses of Cs/Sr have only a small impact, unless the losses are much greater than 1.0%.

- d. Higher TRU losses to the HLW will significantly affect the radiotoxicity, since the reduction in radiotoxicity is mainly due to the much lower TRU content. It can be estimated that if the loss of TRU to the HLW were 1.0% instead of 0.1%, the radiotoxicity after 400 years or so (when isotopes of plutonium and americium dominate) would increase by almost a factor of 10, delaying the time at which the waste had decayed to the natural uranium ore from 375 years out to about 8,000-10,000 years. Higher TRU losses to the waste stream would delay the decay time even further. At the same time, the impact of higher loss of Cs/Sr would be limited to the first few decades after the fuel was discharged from the reactor, since the effects of Cs/Sr are relatively short-lived.
4. Fast and Thermal reactor recycle alternative – All spent LWR and fast reactor fuel is processed in this case as in the case where only the fast reactor is used for recycle. As a result, the impacts of higher losses of TRU and Cs/Sr would be essentially the same.